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HYDRAULIC CEMENT.

A HAND-BOOK

FOR

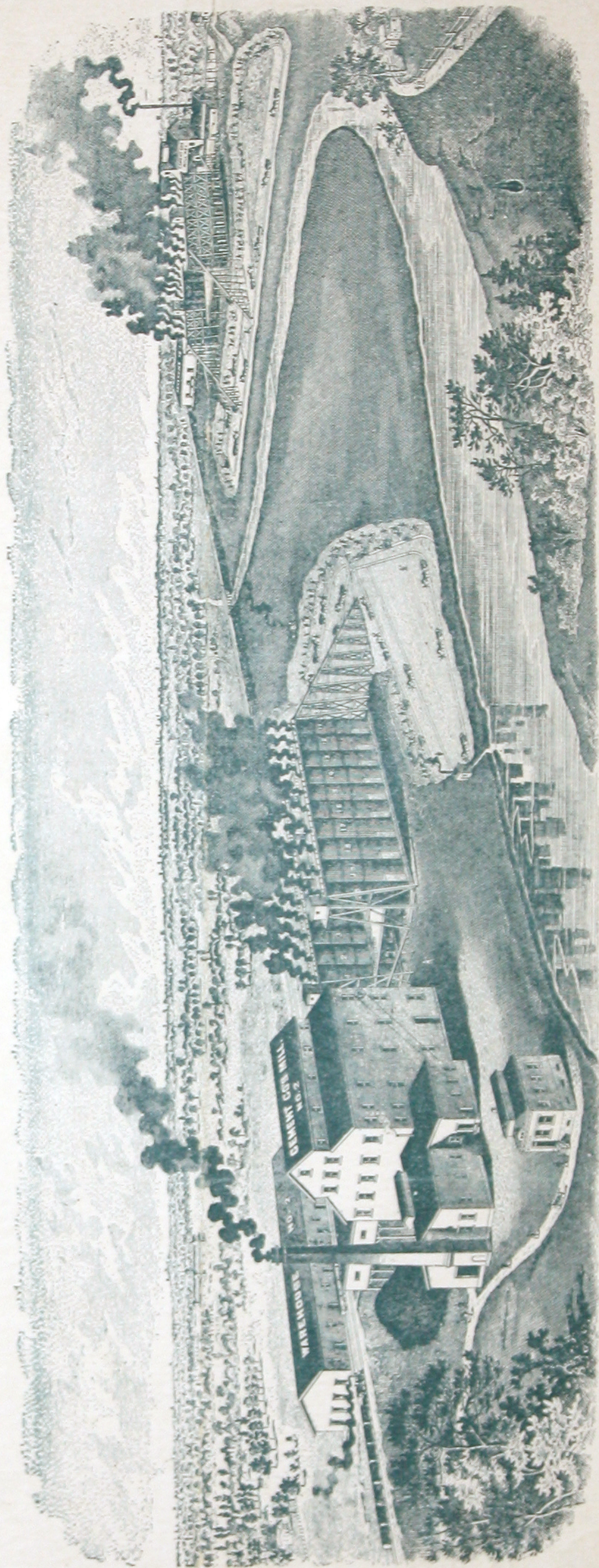
ENGINEERS, ARCHITECTS, MASONS
CONTRACTORS, BUILDERS
AND DEALERS.

HOW TO BUY: HOW TO TEST IT: HOW TO USE IT AND
NOT TO ABUSE IT: WITH TESTS MADE OF IT, AND
OTHER PRACTICAL INFORMATION.

WITH

REFERENCES TO THE MOST EMINENT AUTHORITIES
OF EUROPE AND THE UNITED STATES.

MILWAUKEE:
PUBLISHED BY SWAIN & TATE.
1890.



CAPACITY 4000 BBLS. DAILY.

MILWAUKEE CEMENT CO'S MILLS.

MILWAUKEE, WIS.

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INTRODUCTION.

To educate the public mind with respect to the true quality of cement is one of the first and most urgent duties of manufacturers and competent engineers. Unfortunately, instruction in this most important department of practical engineering is comparatively neglected in the universities and colleges of this country where engineers are graduated. Moreover, engineers of the largest knowledge and experience have not been wholly agreed upon a uniform method of determining the character of cement, and serious errors have occurred in methods employed.

In the practical use of cement, the full extent of the prejudices and delusions which now prevail, often at great extra cost to cities, corporations and private parties concerned in construction of important works, can scarcely be estimated. Cement known to be of a quality sufficiently high to warrant its use in the ponderous walls of a state capitol or the piers of a railway bridge is often rejected in the construction of a cellar or small cistern; and large prices are often paid for inferior cements, because of the prejudice or whim of a subordinate employé, who mistakes the quickness, or some other unimportant characteristic of the cement he uses, for proof of quality.

To aid in the removal of prevailing errors and false impressions with regard to the character and treatment of cement, to indicate the most practical and approved methods for testing its quality and to encourage its more general and intelligent use, is the purpose of this little book.

We may add that nothing is stated herein, either as to the nature of cement or as to the proper method of testing and using it, which is not supported by the highest authority and the results of practical investigation.

THE AUTHOR.

DEFINITIONS.

CEMENT.—A substance used to make the surfaces of solid substances adhere to one another. It is applied in a liquid or viscous state and hardens after the surfaces are brought together.—*Chambers' Encyclopædia*.

HYDRAULIC CEMENT.—Burnt stone finely ground, and possessing the property of hardening under water.—*Trautwine*.

HYDRAULIC LIME.—A stone, the proportion of whose ingredients which impart hydraulicity is so small that the burnt stone will slack, but still make a paste which will harden under water.—*Trautwine*.

CONCRETE.—A mass of stone chippings, pebbles, etc., cemented by mortar, and used for foundations when the soil is light or wet.—*Webster's Dictionary*. Also used often (as in this book) to describe a mixture of hydraulic cement with sand or other solid material.

BETON.—Artificial stone, formed by mixing broken stone, gravel, etc., with hydraulic cement.—*Trautwine*.

SETTING.—This term implies merely the condition in which cement has ceased to be paste, and has become brittle.—*Trautwine*.

As to Tests of Quality.

Uniformly Successful Use.—The sale of more than a million barrels of cement of the same brand, manufactured from the same quarry in the same way, and its uniformly successful use in works requiring the highest degree of permanent strength for a period of ten years, might be safely accepted as such evidence of reliable quality as to obviate the necessity of rigid tests.

Necessity of Tests.—Unfortunately the stone of many cement quarries is not similarly homogeneous and reliable. The layers widely vary in composition, and the results are dependent upon uncertain skill in selection, or in compounding the burned stone with artificial mixtures. In other cases, cements which set quickly, and are therefore apparently excellent, indeed oftentimes popular because of their merely apparent energy, are, in fact, of no value. Such cements tend to crack or soften with age, especially under water, and frequently exhibit less strength in thirty or sixty days than in twenty-four hours.* In such cases, experimental investigation is the only guarantee of safety.

True and False Tests.—Ordinarily, those tests which merely exhibit the setting properties of commercial cements within twenty-four hours, or even at seven days, are comparatively worthless as showing ultimate strength; and it may be accepted as a probability in all cases, that the cement which shows the greatest activity in setting within seven days, is less valuable than a cement which sets more slowly. In brief, that cement only is best, which crystallizes gradually, and continues to gain in strength, in water or out, daily thereafter, with uniform progression to ultimately excellent results. The characteristics of good cement in this particular are explained and confirmed by all standard authorities†, by multitudes of tests, and by all human experience. Yet many of those who conduct experiments in this most important department of engineering and practical construction, although perhaps the last to assume the superiority of plaster of Paris and quicklime, as hydraulic cements, because of their prompt exhibition of energy, often demand precisely similar conditions of crystallization as an evidence of high quality in hydraulic cement.

*See Gillmore, *passim*.

†See Grant, Reid, Gillmore and other authorities.

Activity not Hydraulicity or Strength.—It is scarcely necessary in this place to give any special reasons of the apparently essential characteristics of a standard cement above named. Upon that point it is proper to say, simply, that the precise relation of the ingredients of cement stone, in their chemical action when calcined and combined with water, are not yet wholly understood and agreed upon. It may be assumed as a general fact, established by practical results, however, that those ingredients of a cement stone which in excess, induce great activity in the calcined cement, are not those which promote a high degree of hydraulicity and strength, but generally the reverse.* The artificial cements are sometimes referred to as furnishing ground for a contrary conclusion, because of their comparative activity and assumed strength at maturity. But, as we have shown in another place, the so-called Portland or artificial cements of Europe are subject to the same law; and even were the fact otherwise, the conclusion is not yet demonstrated that an artificial Portland cement is superior in strength to some of the natural cements of the United States, when fully mature.

Manufacture.—The fineness of cement relates not only to care and skill in manufacture, but also to the perfection of the machinery employed. A finely ground cement of the standard at which Milwaukee cement is made, is justly regarded as possessing greater ultimate strength and a greater market value. Obviously, it has more capacity for carrying sand than a coarser product. This fact is evidenced by the mechanical relation of cement to sand in mixture. Finely ground cement and coarse sand necessarily would produce more acceptable results than fine sand and coarse cement; if for no other reason, because the aggregate amount of surface exposed to the action of the cementing material in the one case is relatively much greater than in the other. No test of cement can be complete which does not refer to fineness and uniformity of manufacture, as well as to the natural quality of the stone.

*Within the range of the experiments which furnish the tables of this work, it is somewhat remarkable that the quickest cements gave the worst results, and the slowest ones the best.—*Gillmore*, p. 81, *Edition 1874*.

Some cements possess, in a marked degree, all the objectionable properties of the intermediate limes of setting rapidly when first mixed into paste and immersed in water, but possessing no permanence or stability.—*Ibid.*, p. 152.

Quick setting cement has generally too large a proportion of clay in its composition, * * and turns out weak, if not useless.—JOHN GRANT, *Experiment on the Strength of Cement*, LONDON, 1875. The longer it (Portland Cement) is in setting the more its strength increases.—*Ibid.*, p. 14.

How to Test Cement.

IN A PRACTICAL WAY.

Tests made by persons not accustomed to strictly accurate methods, or deprived of the proper facilities for thorough scientific investigation, are often less reliable than tests in a practical way, made in the manner described below.

Mold a small ball of pure cement—one inch in diameter is large enough—with enough water only to make it plastic. Expose it to air; if good it will harden in two hours or less, and grow harder daily in air or water. Cement which endures this test may be accepted as sufficiently fast, and of standard quality for any ordinary purpose, and any failure of such cement to give satisfaction in actual use should be attributed at once to faulty manipulation, bad sand, excess of water, pressure of water, or low temperature of atmosphere or water. Any or all of these causes will retard crystallization, regardless of the quality of the cement, and are no just reasons for complaint against the cement itself. If a ball of cement made in the way above described, cracks, crumbles or softens at any time within ten days after being immersed in water (to which length of time this test should always be extended), the cement is unfit for use.

BY MORE ACCURATE METHOD.

Engineers and others having charge of works requiring very accurate determinations of the strength-value of materials, often require such tests of mortars used as to exhibit, separately, the fineness, and the tensile, breaking, crushing, adhesive and cohesive strength of such mortars, as the circumstances in each case seems to require. The fact seems to be, that neither one of these tests separately furnishes absolute evidence of quality in the other particulars named.* It is generally conceded,

*Mess. Dyckerhoff, in testing the relation between tensile and compressive strength found the general result was, that the compressive was about twenty times that of the tensile strength.—*Grant on Portland Cement.*

Trautwine estimates adhesive strength to brick three-fourths the tensile strength.

however, that the *tensile* strength-value of cement, of standard fineness, furnishes the safest indication of general quality for all ordinary purposes, and investigations in this department are now mostly confined to the determination of the tensile strain per cross section of one square inch.* The following rules of procedure in such tests are sanctioned by the highest American and English authorities :

Selection of Samples.—In selecting cements for test purposes, procure equal and sufficient quantities from the interior of at least five different packages in each one hundred packages, and mix the same thoroughly, thus ensuring a fair average sample of the whole quantity subject to test. Carefully exclude such samples from light, and especially from moisture or a humid atmosphere, until the same is required for manipulation.†

Manipulation of Test Samples.—Mix with a strong spatula, or trowel, thoroughly and quickly, a sufficient quantity of sample cement to fill the standard mould hereafter described with water at a temperature of not less than 60 degrees Fahrenheit, upon the smooth surface of a non-absorbent slab of iron or stone. The accuracy of the result depends largely upon the precise quantity of water used in this process of mixture, but as no two brands of cement require the same quantity of water to produce an equal consistency, no invariable rule can be laid down with regard to it, except that *no more* water should be used than *absolutely necessary to render the mass homogeneously plastic*, and not so much as to prevent the perfect solidity of the mass when pressed into the mold—in other words, *the least amount practicable* in the performance of the experiment. Should more be used, the sample will be proportionately weak,‡ because of the ultimate

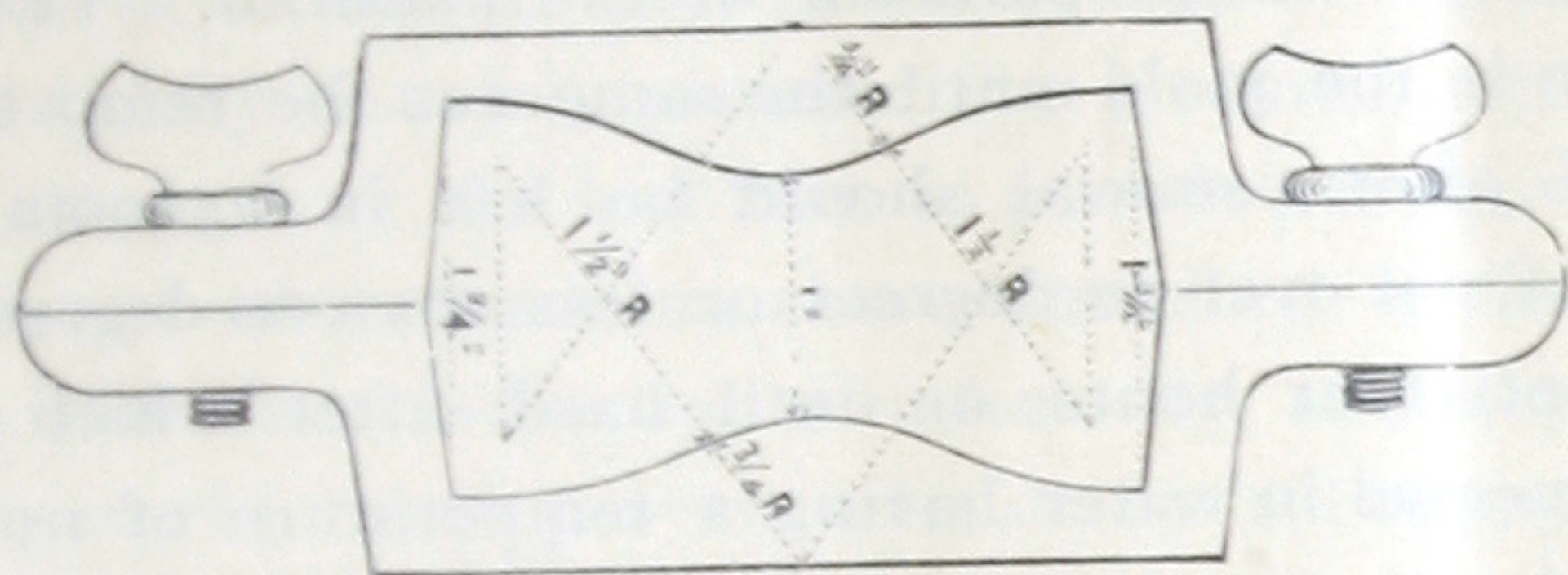
*German authorities have adopted the system of fracturing briquettes by a gradually applied tensile strain.—*Scott and Redgrave*. The section of the test briquette at the point to be fractured is only, in the German machine, 0.775 square inch. The section has been carefully considered in Germany. It is one which no doubt reduces to a minimum the chances of flaws and imperfections in the sample.—*Ibid*. The samples for tests of English cement to be molded to a size giving one square inch of sectional area for fracture.—*Ibid*.

†To reduce the risk of error to a minimum the average of ten tests should, if possible, be taken. *Grant on Portland Cement*.

‡An excess of water weakens either cement mortar or concrete.—*Grant on Portland Cement*, 1880. *With hot or quick-setting cement more water will be required in making tests of neat cement than with cool and slow-setting cement.*—*Ibid*.

evaporation of the excess, leaving the sample comparatively porous. The proportion of water to cement used in England for test experiments is usually about twenty per cent. by weight for slow setting cements, and a larger proportion for quick or hot cements. For obvious reasons, quick-setting cements will appropriate more water than slow-setting for an equal consistency, and require more in practical use.

Form of Mold and Briquette.—The form of mold and briquette most in use by American engineers, and which may be now regarded as the standard form in this country and England, is shown in the illustration below, drawn to a scale of one-third actual size.



The mold itself should be made of iron or brass, one inch in thickness, one inch in narrowest section across inside opening, and otherwise as shown in the figure, except that the two halves can be more safely held together by a simple form of clamp, than by the thumb-screw shown. The use of larger molds for the determination of tensile strength per square inch has been generally abandoned in this country, for the good reason that more recent experiments have indicated no true proportion between the tensile strength of samples of one inch square section and those of a larger dimension. It should be observed, that the mold exhibited above, is so shaped that the two halves can be separated with the greatest practicable factor of safety to the sample, and that the shape of the sample is such as to ensure the most equitable application of the strain, and a transverse breakage at the least sectional diameter, representing at that point precisely one inch.

Molding the Briquette.—The sample of cement, when duly prepared as hereinbefore described, should be immediately deposited in the mold, and pressed carefully and firmly to place with the spatula or trowel, in such manner as to form within the mold a solid, compact and homogeneous mass, free from air or excess of water—especially as to that portion of the briquette ultimately to be

subjected to the strain of the testing machine; and the surface of the briquette should be left perfectly level with the surface of the mold. In this process of filling the mold, too much care cannot be taken to avoid the deposit of the cement in layers, or with such irregularity of pressure as to deteriorate or destroy the accuracy of the ultimate test. The result also depends much upon the degree, as well as upon the evenness of the pressure applied, and in this the candid experimenter must be largely guided by judgment and experience in order to attain the most desirable conditions for accurate results.* Should water appear upon the upper or under face of the sample in molding, it will furnish sufficient evidence of the use of too much water in the preparation of the material. The briquette should remain in the mold until the same can be removed without breaking, and after removal should be left in a room having a temperature of not over 70 degrees or less than 60 degrees Fahrenheit, for twenty-four hours, or until hard, after which the same should be immersed in water having a temperature of not less than 60 degrees Fahrenheit.

Time Required.—To test the tensile strength of cement with an approach to accuracy, the best rule requires that each sample briquette prepared for the purpose shall remain *in air one day, and in water not less than twenty-nine days*. Much greater accuracy is attained when the sample briquettes are permitted to remain in water sixty, ninety, or one hundred and twenty days, or even a longer period.† The exact time at which good cement reaches maturity is unknown, but the fact is well ascertained by actual and numerous experiments that many cements arrive at maturity at a much earlier date than others, and that such cements are ultimately less durable

The slightest want of uniformity in the smallest appreciable condition will effect the results to an extent which will make them worthless for comparison, and which only those who have had considerable experience could believe.—"Portland Cement, its Nature, Tests and Uses."* By John Grant.

†The tests are applied (by German authorities) twenty-eight days after making the samples, during twenty-seven of which it has been placed in water.—*Scott and Redgrave. No cement should be rejected before the test at twenty-eight days has been made.—Portland Cement: "its Nature, Tests and Uses."* By John Grant, 1880. In FOUR WEEKS a fair and practically accurate judgment may be formed; though if for experimental purposes a number of different cements be tested simultaneously every month for, say, a year, THOSE WHICH WERE SECOND OR THIRD AT THE END OF A MONTH MAY OVERTAKE AND SURPASS THE FIRST.—*Ibid.* Long experience has shown that no sound conclusions can be drawn from tests made with neat cement, especially after an interval of ONLY SEVEN DAYS.—*"Portland Cement: its Nature, Tests and Uses."* By John Grant.

and reliable.* It is unfortunately true, indeed, that sometimes briquettes of cement are not only imperfectly made, but are subjected to test within seven days, or even in twenty-four hours after their manufacture. But such tests are obviously superficial, and determine no fact with complete accuracy, except the activity of the cement in setting. In case the necessity of circumstances should require tests to be made within seven days, allowance should be made for the probable and more certain results at a longer period of time, and all estimates of comparative values be deferred for further investigation.

Standard Strength.—Tests of American natural cement at seven days, one day in air and six days in water, exhibit a great variety of results; but it may be safely assumed that a cement which indicates an average strength of not less than 40 pounds per square inch, from five samples or more made as above described, in the time stated, exhibits no immediate indication of inferiority, and may be accepted for ordinary work, unless proven inferior by subsequent tests at a longer period of time. At the end of thirty days, the average of the same number of samples should more than double the figures given, in which case cement of otherwise good reputation from previous use may be regarded as reliable. Artificial, or Portland cement, gains strength more rapidly on all first trials, but with apparently exhausted energy at greater age; and comparative tests of natural and artificial cements at 100 days, or one year and longer, generally show a rapid diminution or entire absence of difference. On this fact is based an apparently correct opinion, that the difference between natural and artificial cements is a difference in activity merely, and not a difference in ultimate quality.

Fineness of Cement.—The inherent value of cement is not necessarily destroyed by incomplete calcination and inferior grinding, but the full development of value, and especially of its capacity to carry sand, are thereby seriously impaired. The rule is, that the finer the cement and the more complete and uniform the calcination, the

*If the relative strength of two or more cements has to be ascertained, not only must all the conditions be uniformly observed, but for accuracy many months must be allowed to elapse between making the briquettes and testing them.—*Ibid.*

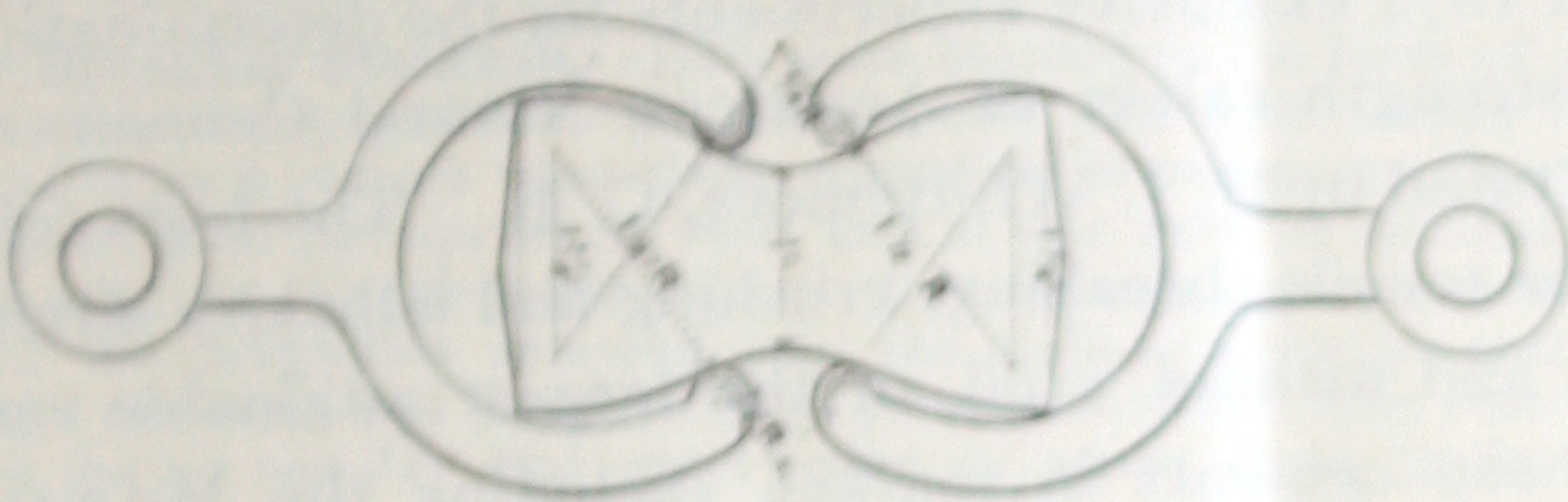
greater the practical value of the cement per weight.* The fact that a cement insufficiently burned and ground tends to exhibit greater apparent activity in crystalization, does not excuse the acceptance of such inferior cement in preference to a superior article, manufactured with greater care and perfection. Some of the so-called cements in market, in fact, cannot be burned thoroughly without seriously impairing their setting property. The increased practical value of a cement finely ground, will be understood by those who understand the relations of cement to sand in the manufacture of concrete, the covering of the sand particles, and the bond of the concrete, being largely enhanced in proportion to the fineness of the cement. Facility in use is also increased. Unfortunately, no exact standard of fineness has been agreed upon among experts in this country or Europe, and judgment upon this point is largely determined by comparative tests. It is safe to assume, however, that 75 per cent. of the bulk of a properly manufactured American cement will pass through a sieve of 2,580 meshes to the square inch.†

Machine and Clutch.—The standard appliances in use for testing the tensile strength of cement mortars, including the mold, are after designs by John Grant, member of the Institute of Civil Engineers, London, England, modified by D. J. Whittemore, C. E., late President of the American Society of Civil Engineers and Chairman of its Committee on a "Uniform Method of Cement Tests." These appliances are now in daily use at the works of the MILWAUKEE CEMENT COMPANY, and all cement shipped is tested by them and the

*Improvements that have taken place in manufacture, especially in respect to more uniform burning and grinding, have rendered it possible to make a given quantity go much further.—*Portland Cement—London, 1880.* Of the value of fine grinding, when the cement is intended to be used with sand, the experiments of Mr. Colson furnish conclusive evidences.—*Scott and Redgrave.* Coarsely-ground cement will, as a rule, give somewhat higher results when tested neat than finely ground; but when mixed with sand, the superiority of the finely ground becomes apparent.—*Grant on Portland Cement.*

†The German regulations comprise grinding to such a degree of fineness that when passed through a sieve having 5,806 meshes to the square inch, it shall leave a residue not exceeding 25 per cent.—*Scott and Redgrave.* Also, *Grant on Portland Cement, 1886.* Many samples of commercial cements were secured, as fresh as could be obtained, rejecting that part of each sample not passing through any sieve of 2,704 meshes to the square inch.—*D. J. Whittemore, Strength Value of Milwaukee Cement.* The following might be the general tests for English cements: The whole of the cement to be ground fine enough to pass through a sieve of $40 \times 40 = 1,600$ meshes per square inch without residue, etc.—*Scott and Redgrave.* Of 50,000 tons of Portland cement supplied, about 75 per cent. by weight will pass through a sieve of 50 meshes to the lineal inch (2,500 to the square inch).—*Berways on Portland Cement.* In England the residue would be from 15 per cent. to 27 per cent. with a sieve equal to 2,580 meshes per square inch.—*John Grant.*

results accurately recorded. Such machines may be obtained of two or three manufacturers in the United States, at a moderate cost. The form of clutch, with its application to sample briquette is exhibited below, drawn to a scale of one-third actual size:



Care should be exercised in the application of the tensile force to the sample, so that the increase of stress shall be at a rate at least 200 lbs. per minute until rupture.

NOTE.—The application of a definite pressure to experimental briquettes in process of manufacture, (32 lbs. to the square inch being the more usual rule), although the most practicable condition for accurate conclusions in some cases, is liable to the objection that equal pressure does not always secure equal consistency of the sample.

Another theory, that cement mortars should be tested only when in the exact plastic condition required in practical use, has no support except in an occasional necessity for ascertaining the initial strength in a given case. The conditions existing in practical use are necessarily variable, and infinitely modified by time, accidents and special circumstances; and thus permit no positive standard of judgment for determination of relative quality. A ludicrous example of the latter method was recently presented by the publication of a series of comparative results obtained by shoveling soft cement mortar, of indeterminate consistency, into larger wooden molds or boxes, from which test samples were periodically separated with a saw!

Cement is often tested after admixture with sand, and expert engineers are disposed to encourage such tests to a limited degree—the proportion of sand not to exceed one-half the whole weight of sample. Qualities of sands, however, are infinitely various, and in comparative tests, its use seems to multiply the conditions of certainty. In special cases, tests with sand are undoubtedly useful and often necessary.

Strength-Value of Cement.

TESTS BY D. J. WHITTEMORE, C. E.

In 1874 extensive experiments for the determination of the strength-values of American Natural Cements were instituted by D. J. Whittemore, C. E. The tests related to the tensile, breaking, crushing and adhesive strength, with and without sand, of the largest attainable variety of these cements in market, including the MILWAUKEE CEMENT, then but recently discovered. There is no record of a more complete and impartial inquiry in this direction, under the personal supervision of any American Engineer, for the length of time included. The results obtained were comparatively high—a fact partly due to the discriminating care with which the manipulation was conducted. All samples were selected, mixed, weighed, measured, stored, manufactured and tested with scrupulous and conscientious nicety and impartiality. That portion of each sample of dry cement not passing through a sieve of 2794 meshes to the square inch was rejected. The method adopted by Mr. Whittemore in the manufacture of samples is thus described by himself.

For Tensile Strength.—Briquettes were molded into a bar with enlarged ends, and having a breaking section one and one-half inches square, or an area of two and one-quarter square inches. The results I shall give of tensile strength are derived from averages of two or more trials of each sample. The mortars were compacted in the mold by ramming, somewhat like beton agglomere, using, however, a rammer of but a few ounces in weight—usually the handle of the spatula.

For Crushing Strength.—The several gangs of mortar were prepared of the consistency before mentioned, and pressed firmly with the fingers into the molds, circular in form, thus making a cylinder of mortar, having a base area of one square inch and one inch high. The mortar was now subjected to a pressure of 32 pounds, applied without shock or blow. This pressure was continued until

the mortar had set. The specimen was then carefully removed from the mold and kept in a dry room one day; then properly labeled and immersed in water eighty-nine days, at which time it was crushed. From three to five samples of each kind were made, from which the average strength was ascertained. In several instances as high as ten samples were made of each kind.

For Breaking Strength.—Bars were molded in the form of rectangular parallelepipeds, one inch square and four inches long. Mortars of each sample were made, composed of two parts of cement and one of sand for one set of bars, and of one part of cement and two of sand for the other sets—all of the same consistency as in the case of the briquettes, rammed into the mold in a similar manner, and kept under an end pressure of 32 pounds until set; then removed, kept in the air one day and ninety-nine in water; then broken, by resting the bars on supports three inches apart, and gradually applying weight at the center.

For Adhesive Strength.—Common brick were joined together crosswise with a mortar composed of equal parts of cement and sand, kept under a pressure of five pounds per square inch, until the mortar had pretty thoroughly set; the brick were then packed in sand and kept damp for seventy days, at which time they were separated by a tensile strain.

The Sand used for my experiments was dredged from Lake Michigan. When screened, a bulk has uniformly 36 per cent. of voids, and its weight, as determined from many examinations, is quite uniform. In proportioning the cement and sand, in the several mixtures, the following course was pursued: The ring in which the cylinders were molded was filled with dry cement and compacted by a pressure of 32 pounds, slowly applied, the volume ascertained, and then weighed, and repeated measurements and weighing of the same sample gave a close approximation to the relative volume and weight. The weight of the sand ascertained in a similar manner, and, by weights, the several mixtures were proportioned correctly for volumes.

Annexed is a summary of results thus attained, involving more than 1500 individual tests:

TENSILE STRENGTH, IN POUNDS PER SQUARE INCH, OF MORTARS OF CLEAR CEMENT SEVEN DAYS OLD, THE LAST SIX IN WATER; ALSO, OF MORTARS COMPOSED OF EQUAL WEIGHTS OF CEMENT AND SAND AT NINETY DAYS, THE LAST EIGHTY-NINE IN WATER.*

KIND OF CEMENT.	Clear Cement. 7 days.	Sand and Cement. 90 days.	Average.
Commercial Cement, No. 1.....	95	194	192
Commercial Cement, No. 2.....	77	185	
Commercial Cement, No. 3.....	38	152 $\frac{1}{4}$	
Commercial Cement, No. 4.....	97	270	
Commercial Cement, No. 5.....	107 $\frac{1}{4}$	195	
Commercial Cement, No. 7.....	139 $\frac{2}{3}$	204 $\frac{1}{2}$	
Commercial Cement, No. 8.....	44		
Commercial Cement, No. 9.....	36	140	
Commercial Cement, No. 10.....	94 $\frac{1}{2}$	182 $\frac{3}{4}$	
Commercial Cement, No. 11.....	95	280	
Commercial Cement, No. 12.....	98 $\frac{1}{3}$	149	
Commercial Cement, No. 13.....	90	157	
Commercial Cement, No. 14.....	70 $\frac{1}{2}$	196 $\frac{2}{3}$	
Commercial Cement, No. 15.....	101	190	
Commercial Cement, No. 16.....	98	202 $\frac{3}{4}$	
MILWAUKEE CEMENT.....	96	290†	290†

*A special feature of this table is its demonstration of the unreliability of tests at seven days. At this time, tests by tensile strain not being deemed of the same importance as now, unfortunately the tests of *clear cement* were not carried beyond seven days. The tensile strength of *mixed cement and sand* at ninety days, however, are undoubtedly worthy of equal credit.

†A report made by Maj. Gen. Gilmore upon the quality of the Milwaukee Cement Stone, March 29, 1875, states that he found the average tensile strength of the Milwaukee Cement, ascertained by all his experiments to be 64 1-9 lbs. to the square inch, in seven days "which may, perhaps, be assumed as the standard of your quarry as obtained by experiments." Gen. Gilmore further gives the results of his experiments as to the tensile strength of the standard brands of five of the Rosendale Companies, at seven days, the average being 47 lbs. to the square inch, and he therefore certifies, that the result obtained by him from the Milwaukee stone, as above, "is greatly above the average of them all." The actual results in these experiments, in comparison with those of Mr. Whittemore, were more or less affected by the method of tests—but the relative results are substantially the same, and may be esteemed as reliable as most tests at seven days

‡Experiments made by Belgrand and Michelot on clear Roman Cements from "septaria," showed a tensile strength at the age of *one year*, of from 170 to 213 pounds per square inch.

CRUSHING STRENGTH, IN POUNDS PER SQUARE INCH, OF CEMENT
MORTARS MIXED WITH SAND NINETY DAYS OLD, THE LAST EIGHTY-
NINE DAYS IN WATER.*

KIND OF CEMENT.	Proportion of Cement to Sand.				Aggregate 1 to 1; 1 to 2 1 to 3	Relative Value.
	3 to 1	1 to 1	1 to 2	1 to 3		
Commercial No. 1	1930	884	299	128	1311	33
Commercial No. 2	1614	794	337	180	1311	33
Commercial No. 3	1661	1071	417	233	1721	43
Commercial No. 4	2767	1536	812	524	2893	70
Commercial No. 5	2150	939	742	472	2153	54
Commercial No. 6	3060	1590	895	615	3100	77
Commercial No. 7	3475	1737	843	625	3205	80
Commercial No. 8	2396	1596	1068	571	3235	80
Commercial No. 9	3156	1900	955	586	3441	85
Commercial No. 10	2981	2075	1208	750	4030	100
Commercial No. 11	3572	2130	1192	681	4003	100
Milwaukee	3494	2365	1451	1107	4923	123
English Portland	4638	3356	1769	792	5917	148†

BREAKING STRENGTH IN POUNDS PER SQUARE INCH, OF CEMENT
MORTARS MIXED WITH SAND, ONE HUNDRED DAYS OLD, NINETY-NINE
DAYS IN WATER:

KIND OF CEMENT.	Composition of Mortar.	
	2 to 1	1 to 2
Commercial No. 1	54	28½
Commercial No. 3	59	44½
Commercial No. 4	98½	44¼
Commercial No. 7	100	47
Commercial No. 10	59	44¾
Commercial No. 11	107	56½
MILWAUKEE CEMENT	124	69†

*In a large number of experiments conducted by Mr. Whittemore for the purpose of illustrating the degree of induration attained by pure cements, at seventeen different periods within five and ninety days after mixture, there was no large variation at the end of the ninety days, between samples which exhibited an initial strength at five days of over eight hundred pounds and those which exhibited an initial strength at the same age, of little more than half that number of pounds; showing conclusively that, also, as to crushing strength, short-time tests are comparatively worthless.

†It may be surmised that the Portland used by me had not even average strength. With reference to this, I wish to say that John Grant, assistant to Mr. Bazalzet, Engineer of the Metropolitan Board of Works, London, has made more experimental tests on Portland, probably, than all other experimenters combined, and that he gives the aggregate of strengths of mortars of similar proportions and age, within the limits mentioned, identical with mine, though there is considerable variation in the several amounts from which the aggregates are derived.—D. J. Whittemore.

‡The results of tests made by Edmund Yardly, C. E., reported in the transac-

ADHESIVE STRENGTH IN POUNDS PER SQUARE INCH, OF CEMENT
MORTARS, EQUAL PARTS OF CEMENT AND SAND, SEVENTY DAYS OLD,
PACKED IN DAMP SAND.*

KIND OF CEMENT.	1 to 1	Av'r ^g e
Commercial Cement No. 1.....	39 $\frac{3}{4}$	45 $\frac{1}{2}$
Commercial Cement No. 2.....	59	
Commercial Cement No. 3.....	16	
Commercial Cement No. 4.....	27 $\frac{2}{3}$	
Commercial Cement No. 6.....	41 $\frac{3}{4}$	
Commercial Cement No. 7.....	54 $\frac{1}{2}$	
Commercial Cement No. 8.....	41 $\frac{3}{4}$	
Commercial Cement No. 10.....	66	
Commercial Cement No. 11.....	63 $\frac{1}{4}$	
MILWAUKEE CEMENT.....		75 $\frac{1}{2}$
English Portland.....		47 $\frac{1}{2}$

The following is a summary of conclusions derived from the foregoing experiments.

1. MILWAUKEE CEMENT has a greater average *tensile strength* at ninety days by fifty per cent. than the average of the fourteen other hydraulic cements tested.
2. A greater *breaking strength* at 100 days by fifty-six per cent. than derived from the average of the six commercial cements tested.
3. A greater *crushing strength* at ninety days within the included limits of 1 to 1 to 1 to 3, by fifty-four per cent. than shown from the average of the eleven other hydraulic cements tested.
4. A greater *adhesion to brick* at seventy days by sixty-six per cent. than attained from the average of the nine commercial samples tested.

TESTS FOR GOVERNMENT WORK.

A very complete and apparently reliable series of tests of THE TENSILE STRENGTH OF AMERICAN CEMENTS, PURE,

tions of the American Society of Civil Engineers, for the year 1872, on specimens of similar form, composition and age, were as follows: Allen's Pennsylvania Cement, 2 to 1, 64 lbs.; 1 to 2, 82 lbs. Diamond Pennsylvania Cement, 2 to 1, 70 lbs.; 1 to 2, 88 lbs. Rosendale New York Cement, 2 to 1, 62 lbs.; 1 to 2, 20 lbs.

*Experiments of this kind involve an element of so much uncertainty, when a strain of about sixty pounds to the square inch is reached as to furnish no satisfactory measure of the adhesive power beyond that limit; as then, it is often the case that portions of the brick surfaces are ruptured or torn out, and the test simply determines the tensile strength of the brick, instead of the adhesive power of the mortar. Experiments of General Gillmore on the adhesion of cement mortars of similar composition to Croton front brick joined three hundred and twenty days: Rosendale Cement (DeLafield & Baxter), 44 $\frac{1}{2}$ lbs. per square inch; Rosendale Cement (Newark Lime & Cement Co.), 58 lbs. per square inch; James River Cement, 58 lbs. per square inch.

was recently made by a learned civil engineer in charge of important government works in the Northwest. The method of preparing briquettes was similar to that adopted by Mr. WHITTEMORE. The tests are entitled to unusual credit because of the like unusual care and precision of the manipulation, but more especially because of the large number of tests from which the mean results were obtained. Six different natural cements of American manufacture were included in the experiments,* and *each result given is the mean result from seventy-five specimens.* Annexed is a tabulated statement of these results, for thirty and sixty days:

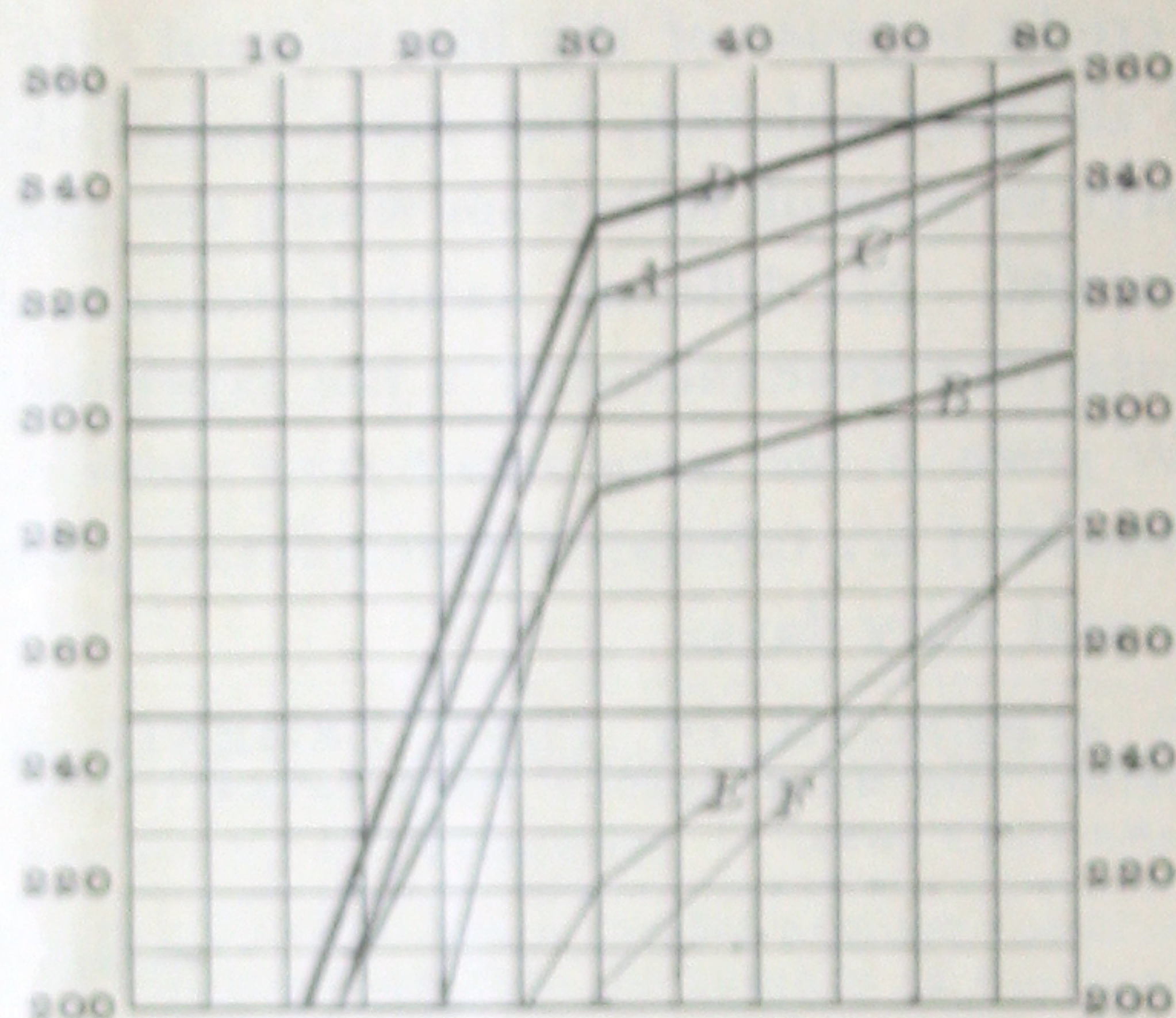
TENSILE STRENGTH OF PURE CEMENTS—EACH TEST GIVEN BEING THE MEAN RESULT FROM SEVENTY-FIVE SPECIMENS THIRTY AND SIXTY DAYS:

	30 days.	60 days.
A Cement.....	320	345
B Cement.....	288	310
C Cement.....	303	330
E Cement.....	220	280
F Cement.....	202	282
D (MILWAUKEE).....	332	350

It will be seen from the foregoing table that the weakest cement of the six, at thirty days, had gained most rapidly during the second period of thirty days. An American artificial "Portland," tested at the same time and in the same way, exhibited an initial strength of thirty-eight pounds *greater* than Milwaukee in seven days, but in less than twenty days this difference had disappeared, and in thirty days the strength of the Milwaukee had exceeded the Portland by over thirty pounds—a striking and instructive example of the

*The cements tested were those most used in the West, with the exception of one or two very quick setting cements. Probably the last were excepted because not deemed of standard quality.

deceptive behavior of artificial cements at short periods of time. The following is a graphic representation of the results of the above tests:



[The figures at the top of the diagram represent *days*, and those at the left of the diagram, *tensile strength per square inch in pounds*.]

These tests were continued for a longer period than sixty days without notable variation in relative results. It should be remarked here, that as in the case of tests by Mr. WHITEMORE, the results are probably higher than those which could have been obtained by manipulation less perfect, or a standard of pressure less great and uniform.

Experiments on the BREAKING STRENGTH of twenty-one samples of Milwaukee Cement, mixed with three parts cement to one part water, by the same engineer, gave an average result of 156.7 pounds in seven days, one day in air and six days in water.

OTHER TESTS OF AMERICAN CEMENTS.

By Gen. Gillmore.—Maj. Gen. Q. A. Gillmore, the most distinguished American author on this subject, made many tests of American cements manufactured in the Eastern States. The results attained by him show no superiority of the eastern cements over the standard cements manufactured in the West. In a large number of tests in the *breaking* strength of pure cements, made into a stiff mortar, with a pressure of 32 lbs. per square inch, the relative average results obtained from rectangular parallelipeds containing four square inches to the cross section, in three hundred and twenty days, scarcely exceeded the results from Milwaukee cement, last noted above, in seven days. The author of these experiments makes the deduction, that "no great advantage appears to be gained by mixing the paste stiff, *provided it is in condition to set under compression.*" Numerous other tests from the same author, serve to confirm the general accuracy of the results obtained by western engineers heretofore cited, and to conform with the same general method of procedure. In a note to a preceding page, Gen. Gillmore's letter attests that the average *tensile* strength of Milwaukee cement is greatly above "that obtained by him from the standard brands of five of the Rosendale companies." Tests of neat Roman cement of Europe by M. Darcey, published by Gen. Gillmore in his "Practical Treatise," etc., show a tensile strength of $142\frac{1}{4}$ lbs. in forty-two days. Roman cement from septaria reached 170 to 213 lbs. in one year.

By Milwaukee Cement Co.—Tests of a large number of briquette, of Milwaukee cement by the superintendent of the Milwaukee Cement Works, during the fall of 1883, with neat cements but with less pressure than usually applied, showed an average tensile strength per square inch of 77 lbs. in seven days, 103 lbs. in thirty days, and 123 lbs. in sixty days.* Similar tests with other standard American cements, exhibited about the same average of tensile strength per inch in seven days, with a decidedly diminished rate of increase at the subsequent times named. In these experiments, the prepared samples of cement were deposited in the mold without ramming.

By Architect Vogdes.—In Vogdes' "Architects and Builder's Pocket Companion," 1883, results are given of a series of tensile tests of seven American cements. The author says: "The cement paste was made moist enough to fill the molds without any pressure. No attempt was made to develop the maximum strength of any cement tested, but to ascertain what strength might certainly be relied upon, when used by ignorant and careless workmen under the disadvantageous circumstances constantly arising during the progress of a large building." In these tests MILWAUKEE CEMENT exhibited a strength of 87 lbs. in seven days and 136 lbs. per square inch in

*The *uniformity* of results from Milwaukee cement is certainly remarkable, when we consider that it is not unusual to find a difference of 66 per cent. in strength of samples taken from different cargoes of reputed good commercial cements of one and the same brand.—D. J. Whittemore.

twenty-eight days, a gain of 49 lbs. in the last twenty-one days. Of the seven well known brands tested, no other exhibited a similar gain during the same time, and but two other brands attained the same degree of strength at the end of the twenty-eight days. In these two cases a *less proportion of water* was used.

By Trautwine.—John C. Trautwine, C. E., gives the average results of about 25,000 experiments with Portland and Rosendale cements, in the years 1878 to 1882. The average tensile strength of best neat Rosendale at seven days (92 lbs.), was found to be precisely the same as the average tensile strength of Milwaukee cement as determined by Whittemore and Vogdes, for the same time, but the average results for neat Rosendale *in one year* by Trautwine does not exceed the average tensile strength of the Milwaukee *one-half sand by weight*, as determined by Whittemore *in ninety days*. In the mean results of experiments with Milwaukee cement for government work, neat cement, as shown in the diagram above, the Milwaukee passed *the one year average* of Trautwine's experiments with Rosendale *in about twenty-five days*. Mr. Trautwine also gives the results from Rosendale, half cement and half sand by weight, at 236 lbs. in one year, against average of Milwaukee given by Mr. Whittemore, of 290 lbs. in ninety days.*

MANIPULATION OF TEST SAMPLES.

It is found from experience that daily practice for at least one or two months is necessary, before even the most intelligent experimenter in the manipulation of samples can be deemed competent to attain any approximate accuracy in comparative tests, dexterity acquired by a much longer practice and study of the subject would alone ensure that degree of uniformity and precision of manipulation that would warrant publication of results for the use of others, and the most learned experts in this department would hesitate to determine the quality of cement with even probable accuracy in a less time than thirty to sixty days.

*There is a large variation in Rosendale product, the quarries being less uniform in character than most western quarries. It is suggested that Rosendale now manufactured under the intelligent supervision of Mr. F. O. NORTON, and possibly some other brands, would show higher results.

Carbonized Cement and Sand.

It is probable that the beneficial results obtained by the so-called process of "carbonizing" cement, or cement with sand, often employed by manufacturers of sewer pipe and artificial stone, is principally due to the humidity and high temperature of the atmosphere in which the pipe or stone is permitted to harden. We are not aware that any accurate tests of the effect of this process have ever been made by any engineer, except Mr. Whittemore. The results of his interesting and valuable experiments in this direction are embodied in the annexed table exhibiting average results from a large number of samples:

AVERAGE TENSILE STRENGTH IN LBS. PER SQUARE INCH OF CARBONIZED AND UNCARBONIZED AMERICAN CEMENTS, MIXED WITH EQUAL WEIGHTS OF SAND:

	NOT CARBONIZED.		CARBONIZED.	
	Age in Days.	Strength.	Age in Days.	Strength.
Commercial No. 1....	64	109	53	103
Commercial No. 2....	64	153	53	171
Commercial No. 3....	64	...	53	249
Commercial No. 4....	74	...	53	162
MILWAUKEE CEMENT..	64	132	53	327

The above tests include all kinds of American cement usually employed in the manufacture of pipe and stone. In these tests, also, all the slower cements improved most rapidly under the carbonizing process.

STRENGTH OF CARBONIZED CEMENT PIPE.

About fifty samples of cement sewer-pipes, four inches in diameter, were manufactured at the Milwaukee Pipe Works of H. BERTHELET & Co., of different natural cements of the highest reputation, including a proportionate number of samples from Milwaukee cement. The proportion of the ingredients adopted was one part

cement to two parts sand. All the samples were manufactured at the same time and in the same manner, then carbonized, and the whole crushed separately, fifteen days after manufacture, in the presence of a party of engineers and other intelligent gentlemen. *The samples of pipe manufactured from Milwaukee cement withstood an average pressure of 3,380 lbs., over 27 per cent. greater than the average pressure sustained by the samples manufactured from the best cements previously employed for that purpose.*

Portland and Natural Cement.

Among the conclusions from 25,000 experiments given by Mr. Trautwine, is the following: "Good Portland cements (neat) have at the end of a year from one and one-half to two times their strength at seven days, and the American natural cement from two and one-half to three and one-half times." The table of experiments published by Mr. Trautwine shows further, that *in all mixtures with sand*, the relative increase in the tensile strength of American natural cement over Portlands in one year is very much greater than in the case of cements neat. In the tables given by Mr. Trautwine, the average increase of Portland with sand in one year, is less than two and one-half times the strength in seven days, while the average strength of the American natural cements is from four and five to ten times their tensile strength in seven days—the relative strength of the American natural cement increasing with the proportion of sand used; thus establishing the important fact already known to experts, that the relative gain of Portland cement neat rapidly

*diminishes with age, and still more rapidly used with sand.**

As to adhesive strength, the differences in favor of American natural cements are still larger, the experiments of Mr. Whittemore showing that the strength-value of Milwaukee cement mixed with sand is greater in this respect than Portland, at ninety days. Portland cement is notably brittle and inelastic; and other things being equal, is to this extent comparatively less reliable in resisting impact or sudden shocks, such as are common to railroad bridge piers, pavements, floors, foundations of engines, etc.

By the carbonizing process in the manipulation of artificial stone practical maturity of strength is secured in about six days, thus approximately annihilating any differences in favor of Portland cement, arising from greater activity.†

The cost of Portland at Chicago or Milwaukee is over three times that of the American natural cements, per barrel, from which it may be fairly inferred that even when special and extraordinary strength is desired, it is more economical and equally safe to use American product with less proportion of sand than is ordinarily allowed in the use of imported artificial cements. Mr. Trautwine alleges with truth, that "*any common*

*In Trautwine's tables of results obtained from mixture of 1 part cement with 3 parts sand, the increase of Portland over its strength in 7 days, was 36 per cent. in one month, and 52 per cent. in six months; while the American cement increased over its strength in 7 days, 100 per cent. in one month and 160 per cent. in six months.

†We find the best brands for sewer, well and culvert pipe, cement fences, sidewalks, blocks for houses, foundations, etc., the Milwaukee natural cement, except for surfaces exposed to immediate wear, for which we sometimes use a small portion of artificial cement. *All concrete composed of two parts sand and one part Milwaukee hydraulic cement, when matured, will be as strong and durable as rock.* The carbonizing process will ensure this result in six days. We think the time near when cement will be used for buildings of all kinds, in place of stone or brick.—*Racine Cement and Pipe Co.*

When the specifications for the sand test were raised by the department of docks, city of New York, no English brands fulfilled it, and were consequently rejected.—*O. M. Alsen & Sons, Circular, 1884.*

United States cement, if of good quality, will, with one and one-half to two measures of sand, give a mortar strong enough for most engineering purposes." The same author further states that "Portland cement is fit for most engineering purposes with twice the sand that American cements will take for same strength,"* from which we may conclude that a good American natural cement with one part of sand is at least equal for most purposes to Portland with two parts sand, and therefore far more economical in cost for ultimate strength.†

Since natural cements are declared by the best engineers of all countries to be "*strong enough for most engineering purposes,*" even *with twice their measure of sand,*‡ any necessity of resorting to the use of foreign artificial cements seems to be practically obviated in all cases.

*See "Civil Engineer's Pocket Book," etc., 1885, page 502.

†The difference between artificial and natural cements seems to be occasioned by the presence of a limited percentage of carbonate of magnesia in the latter, in place of a portion of the carbonate of lime in the former. While the magnesia tends to retard the activity of setting, it is believed to be still more valuable than lime in the ultimate result. Gillmore says—"Practical Treatise," p. 504: "Magnesia plays an important part in the setting of mortars. . . . During calcination, the carbonic acid is driven off, leaving protoxide of magnesia, which combines itself like lime in the presence of silica and alumina, by forming silicate of magnesia and aluminates of magnesia. These compounds become hydrated in the presence of water, etc. We know that the carbonate of lime is more soluble in water holding carbonic acid and certain organic acids of the soil in solution, than the carbonate of magnesia."

‡Treatise.—"Civil Engineer's Pocket Book."

Uses of Hydraulic Cement.

From the dawn of civilization hydraulic cement has ranked as the most valuable of all constructive materials. It resists water, moisture and fire, is a non-conductor of heat and cold, is comparatively proof against the destructive influences of the atmosphere, defies all ordinary causes of disintegration and decay, and grows continuously stronger with the lapse of time; thus apparently reversing nearly all those natural laws which limit the permanence and strength of other materials. It is also preservative of other materials employed in association with it,* is convenient in use and economical in cost. The following are some of the uses to which hydraulic cement may be profitably applied:

Cement and Lime Mortar.—Ordinary lime mortar, when exposed to the continuous action of water often disintegrates.† Exposed to constant moisture, it will never harden properly; even when very old and hard it absorbs water freely.‡ In tenacity or cohesive strength and in transverse strength, lime mortar has no appreciable value in comparison with cement.§ The lime in mortar, also in close damp situations, decays wood badly.||

In Residences and other Buildings.—In stone and brick work, for buildings of any kind, the use of hydraulic cement is absolutely

*The writer found by ten years' trial, that if after setting, dampness is absolutely excluded, cements preserve iron, lead, zinc, copper and brass—*G. C. Trautwine, C. E.*

†Chamber's Encyclopædia.

‡On too great a proportion of our public works, the common lime mortar may be seen to be rotten and useless, where it has been exposed to moisture, which will be carried by the capillary attraction of the earth to several feet above the natural surface; or as far below the artificial surface of embankments deposited below abutments, retaining walls, etc.—*G. C. Trautwine, C. E., p. 496.* Very pure limes are the worst of all for such exposures, or, are *bad weather limes*; and in important works, *should ever be used with out cement.* Ibid, p. 407. Grout is merely common mortar made so thin as to flow almost like cream. It is intended to fill interstices left in the mortar joints of rough masonry; but unless it contains a large amount of cement, it is *probably entirely worthless.*—Ibid, p. 497.

§The lime mortar used in the foundations of the Washington monument was found soft twenty-five years after it had been placed there.

||The tenacity or adhesive strength of good common mortar of the usual proportions of lime and sand, and six months old, is about from 15 to 30 lbs. per square inch.—*Trautwine.* A bar 1 inch square, 12 inches clear span, 6 months old, breaks with a center load of 4 to 8 lbs.—Ibid.

[*Trautwine, p. 497.*

essential to permanence or proper strength. This is especially true in a climate where buildings, especially residences, are subject to the continuous attacks of rain, frost, snow and strong winds.* The exclusion of moisture from cellars and from brick and stone walls of residences, and thus the preservation of the health of inmates, alone, should be sufficient consideration for the use of cement in all buildings of this class. There is authority for the belief that buildings plastered wholly with lime mortar are not perfectly safe as residences until many months after the mortar is put on. In foundations, in walls, in areas, in pointings, in chimneys, in cellar floors, in copings, in arches, in roofing, in all exterior and even interior plastering, cement is not only the most reliable but most economical source of security, for persons or property. For further evidence of the value of cement as to strength and dryness, see note below.† In all constructions of government buildings, and other permanent buildings, erected in the United States and Europe, hydraulic cement is necessarily and properly a prime factor in the work of construction. The rejection of cement for these purposes on the ground of economy, has no substantial foundation, since the best American cements now cost but little more per barrel than lime. It is true that lime expands in use, but it is equally true that, even if economy were the sole consideration, a greater strength is practicable with a much larger proportion of sand, and that the bulk of mortar used with even better results may be much less. Obviously, it is not wise to lay brick or stone in mortar ultimately weaker than the material itself.

*Wind of 70 miles an hour is sufficient to blow down chimneys and unroof houses, unless they are well built. Ordinary trees will not stand under it. The pressure on a square foot is in the neighborhood of 50 lbs.—*Prof. Holden, Director Washburn Observatory*. The U. S. Signal Service has a record of 600 tornadoes, largely occurring in the West.

†Immersed in water, either a good common or pressed brick, will in a few minutes absorb $\frac{1}{4}$ to $\frac{1}{2}$ lb. of water.—*Franklin*. In some English experiments, small cubical masses of pressed brick, in best Portland cement is said to have withstood 502 tons per square foot; and with common lime mortar only $\frac{1}{4}$ as much.—*Ibid.* Tensile strength of brick varies from 40 to 400 lbs. to square inch.—*Ibid.* (Not greater than average cement used when properly mature, and probably not greater in case of common brick, in the United States, than concrete of cement and sand.) Wall-rot is the consequence of continued moisture in the wall through which a dissolving of the bricks and mortar takes place.—*Brick, Tile and Metal Review*, on authority of E. Miller, German Chemist. Vogdes gives the result of an experiment with American cement one part, and lime mortar three parts, in which the pier broke at 2,552 lbs., while with the plain lime, the crushing strength was but 1,362.

In Sewers and Drains.—All underground structures are ordinarily subjected to the continuously destructive influences of water and moisture. But cement grows stronger under these influences, and therefore is peculiarly adapted to this class of work. The sewers and other costly subterraneous structures of ancient cities, built with cement, have stood the test of centuries, increasing in strength with the lapse of time. In all parts of the world at the present time, cement, and cement with sand, are the principal materials used in this class of work. If other material is employed, such as brick, or clay, or the manufactures of clay, cement is still required for all jointing, pointing and plaster work. Usually other materials in sewers, especially brick, should be thoroughly covered with cement as a protection from the corroding effects of moisture. The theory sometimes advanced, that cement may be injured by the ordinary acids of sewage, is without foundation in science or human experience.

In Pavements of Streets.—The uses of cement in the pavement of streets is wisely and rapidly increasing in the United States. The general conclusion is, that whatever the nature of the superstructure or surface of roadways, health, economy and durability require the foundation at least to be laid in concrete, or a mixture of cement and sand.* Successful examples of this practice may be found in Washington City, New Orleans, Boston, Chicago, Omaha, Kansas City and other cities, in most of which pavement of this kind is now being laid. The methods of use differ according to circumstances. In most cases the foundation consists of concrete from six to nine inches in thickness, the proportion of neat cement being comparatively small. On this solid sub-structure is placed a surface of stone, or wooden blocks, or a combination of sand or broken stone, with cement and natural asphalt.† In case wooden blocks of any form

*The following are suitable foundations for street pavements, provided their thickness is judiciously adapted to the character of the subsoil and the nature of the traffic (named in order of their value), viz: 1. Hydraulic concrete five to eight inches in thickness. 2. Rubble stone set on edge, side by side, but not in close contact, with the interstices filled with hydraulic concrete, etc.—Q. A. Gillmore.

†The best asphalt pavement is one having a foundation bed of hydraulic cement, or something equivalent thereto in firmness and durability.—Q. A. Gillmore.

Asphalt pavement is thus described by Lieut. Greene: "a foundation of six inches of hydraulic cement concrete and a wearing surface of bituminous mastic, (Trinidad Asphalt, petroleum oil and sand) laid in two coats, respectively a half inch and two inches thick when compressed. The theory of this

are used for surface, a large degree of security against decay is obtained by ramming the intervening space with concrete.* In other cases durability is obtained by a layer of concrete employed between the sub-structure and superstructure of the pavement. Among the merits claimed for asphalt pavement constructed with concrete foundation are security from frost, disease, noise, and injury to horses and vehicles; also elasticity, cheapness of construction, the facility for cutting through, and in the economy for renewals and repairs. The cost is estimated at less than one-half that of any other pavement. The latest authorities in behalf of concrete in this connection are numberless, and thus far such pavements endure the severest tests of wear and climate.

For Wells.—In the construction of wells, cement in some form has become a general necessity. Nearly two hundred "cement wells" are in use in a single county in Michigan. Whether wells are built with stone, brick or tubing, the value and economy of cement are equally apparent. Well tubing made of cement and sand, and as strong as the hardest stone, is manufactured and held for sale in most of the larger cities. Among the advantages properly claimed for the use of cement in wells is protection against surface water, economy and permanence. When brick are used in this work they should be thoroughly plastered inside and outside with cement. For permanent strength and security against surface-water the slower setting cements afford the largest degree of safety. Quick setting cements, liable to check, crack or soften with age, though often used to hasten the work, should be avoided.

For Cisterns and Reservoirs.—What is said as to the construction of wells with cement, will generally apply to cisterns and

pavement is a solid base of concrete masonry practically imperishable, and a comparatively thin and smooth wearing surface that can be replaced when it is worn out."

(1) It produces no dust, and therefore no mud. (2) It is comparatively noiseless. (3) It does not absorb and retain noxious liquids, but facilitates their prompt discharge into the side gutters and catch basins. (4) It is impermeable to moisture, and never emits nor allows the emission from the subsoil of unwholesomeness and poisonous vapors. It reduces the force of traction, and consequently the wear and tear upon animals and vehicles to the minimum; and (5) It does not become polished and slippery from continual wear.—*Q. A. Gillmore.*

Dr. G. W. Wright, Health Officer, Detroit, also recommends, especially from a sanitary point of view, that "all streets except of heaviest traffic be paved with Trinidad asphalt, on a monolithic bed of hydraulic cement concrete, six inches thick."—*Report, 1882.*

*In England wooden pavement is laid in concrete.

reservoirs, with special and additional care as to firmness of foundation, and proper protection from the pressure of exterior water. Concrete at the bottom of cisterns, should be thoroughly *tamped* down to place, on a firm foundation; interior and exterior walls should be plastered thoroughly, and there should be ample arrangements for drainage. *Cement will not harden when disturbed by hydraulic pressure from underneath, or outside an empty cistern.* As in the case of wells, a slow-setting cement of standard quality, with ample time for crystalization, will prove safest and best.

For Floors and Inside Walls.—Cement excludes dampness, vermin and noxious gases, and furnishes a hard and even surface, which may be adopted to proper drainage. In constructing floors for cellars or malt houses, and in all similar work, the concrete of cement and sand should be tamped down to place, and the proportion of cement to sand should be increased toward the surface. An average of one-half cement to one-half sand, and a thickness of three to six inches, are usually deemed sufficient for work of this kind; but for malt floors, where extra strength and permanence is required, the strength of Portland with sand may be satisfactorily approximated with natural cement, by increasing the proportion of cement. Until thoroughly hard, concrete should be kept thoroughly moist.*

For Outside Walls.—As a mastic for beautifying the exterior of new residences and other buildings, or for strengthening, attractively covering and protecting old and discolored brick walls, no material is superior. In many cities of Europe and United States it is used largely for these purposes, producing a surface resembling stone of any hue desired; and when skillfully applied, it is durable, economical and otherwise valuable.† The cheaper and coarser the brick used with it, the more durable the work.

*Hydraulic mortar must, when used for covering dry walls or otherwise, (after using) be kept moist and watered, until it has acquired its proper degree of hardness—*Byrne's Dictionary of Engineering.*

†It does not by any means follow that because hydraulic mortar is the *only* durable material for building under water, it cannot consequently be used for dry walls. It is on the contrary, of the greatest service whenever protection is required against the infiltration of moisture and damp; and dwellings or buildings can often be rendered very much less damp by a judicious application of a hydraulic coating. A layer of this kind, when once hardened, *is not calculated, like ordinary mortar, to attract moisture and allow it to pass through.*—*Byrne's Dictionary of Engineering.*

For Side-Walks, Garden-Walks, Etc.—Cement enters largely into this department of enterprise, success seeming to depend upon the degree of skill and fidelity with which foundations are laid, and the work put down. Artificial stone, of any acceptable form for street or yard walks, properly made and laid, are found to be permanent, attractive and economical. Street or garden walks of concrete laid in place, with suitable foundations, and so divided at proper distances as to permit necessary expansion and contraction, are frequently preferred to all other kinds, and have become common.

General Uses.—The more general uses of cement require no special description or directions for use not already given. These general uses are almost limitless as to number. In the manufacture of ARTIFICIAL STONE, in the construction of AQUEDUCTS, in all MARINE AND SUBTERRANEAN WORKS, in the PIERS OF BRIDGES, in WATERWORKS, TUNNELS, CULVERTS, FIRE-SAFES, BANK-VAULTS, TILING, ARCHES, ROOFING, PAINTING—briefly, in all structures where strength or protection from water, frost or fire is required, the value of the hydraulic cement is now conceded and its use recommended by all reliable authorities in every civilized land.

How to Use Cement.

The following general rules referring to the practical use of cement will be found convenient for reference.

1. Quality of Sand.—The sand should be clean, sharp and coarse. When the sand is mixed with loam the mortar will set comparatively slow, and the work will be comparatively weak. Fine sand and especially water-worn sand, delays the setting of the cement, and deteriorates strength. Damp sand should not be mixed with dry cement, but the cement and sand should be mixed thoroughly and uniformly together when both are dry, and no water should be applied until immediately before the mortar is wanted for use.

2. Proportion of Sand.—The larger the proportion of cement the stronger the work.* One part of good cement to two parts sand is allowable for ordinary work; but for cisterns, cellars, and work requiring special care, half and half is the better proportion. For floors, the cement should be increased toward the surface.

3. Water in Concrete.—Use no more water in cement than absolutely necessary. Cement requires but a very small quantity of water in crystalizing. Merely dampening the material gives the best results. Any water in excess necessarily evaporates, and leaves the hardened cement comparatively weak and porous.†

4. Concrete in Water.—Whenever concrete is used under water, care must be taken that the water is still.‡ So say all English and American authorities. In laying cellar floors, or constructing cisterns or similar work, care must also be taken to avoid *pressure of exterior water*. Cement will not crystalize when disturbed by the force of currents, or pressure of water, but will resist currents and pressure after hardening only. In still water, good cement will harden

*Neat cement is stronger than any admixture of it with sand.—Grant, p. 14.
The cleaner and sharper the sand, the greater the strength.—Ibid, p. 15.

†Cement, when carefully moistened, and only supplied with sufficient water to reduce it to a state of paste, gave better results than when unduly charged with water. Grant, p. 6. *The stiffer the cement mortar, that is, the less the amount of water used in working it up, the better.* Ibid, p. 15.

‡Whenever concrete is used under water, care must be taken that the water is still; as otherwise a current, whether natural or caused by pumping, will carry away the cement, and leave only the clean ballast.—JOHN GRANT, "*Experiments on the Strength of Cement*, p. 16.

quicker than in air, and when kept in water, will be stronger than when kept in air. Cements which harden especially quick in air are usually slow or worthless in water.

5. How to put down Concrete.—When strong work is wanted, for cellar floors and all similar work, the concrete should be dampened and *tamped down* to place,* with the back of a spade, or, better, with the end of a plank or rammer; then finished off with a trowel, thus leveling and compacting the work. Only persons ignorant of the business will lay a floor or walk with soft cement mortar. All artificial stone is made in a similar way to that described, and when set, is strong and hard as stone.

6. Delay in Use.—Do not permit the mortar to exhaust its setting properties by delaying its use when ready. Inferior cements only will remain standing in the mortar-bed any length of time without serious injury.

7. Stone and Brick Work.—In buildings constructed of stone or brick, the best protection from dampness and decay, and also from the danger of cyclones, is a mortar of cement and coarse sand. The extra cost is inconsiderable, and the increased value of the structure very great. Chimneys laid in this manner never blow down, and cellars whose foundations are thus laid are always free from atmospheric moisture. Cement may also be mixed with lime mortar for plastering and other purposes, to great advantage.

8. Effect of Frost and Cold.—At a temperature less than 60 degrees Fahrenheit, all good cement sets slowly, though surely, but if allowed to freeze its value is seriously impaired. *In cold weather or cold water, do not fear to wait for your concrete to crystallize.*

9. Damage from Moisture.—Good cement is not injured by age, if carefully preserved from moisture. Lumps in bags or barrels of cement are caused by exposure to moisture. They prove the originally good quality of cement.

10. Character of Standard Cement.—The Milwaukee Cement, in this country, and similar cements here or in Europe, are made according to the highest standard of quickness consistent with highest quality. When properly used as above, they never fail. Much of

*The most cursory examination of a piece of ordinary cement mortar will show that a large percentage of the mass is uncombined or imperfectly united, owing to the intervention of the air and water spaces. Were these voids filled, not only would the density of the preparation be increased, but its strength would also be much improved.—*Ship's Store and Art of Manufacture of Cement*, p. 272.

the so-called "cement" sold is simply hydraulic lime, having no special value as cement, but often popular with those who do not distinguish the quality of quickness in air from the quality of permanent strength and reliability in and out of water, ten, thirty or sixty days after use.

CONCRETE FOR FOUNDATIONS.

The following method of putting down cement concrete for foundations is from specifications for pavement in the city of Omaha, laid with Milwaukee cement, and except as to thickness, furnishes a formula for all similar work:

Concrete to embrace a layer of hydraulic cement concrete six inches in thickness, laid to the true curve and grade of the street as per plans and according to stakes set by the City Engineer, to be made as follows: One measure of cement equal to the best quality of American cement, and two of sharp, clean screened sand, free from clay or loam, will be thoroughly mixed dry and then made into a mortar with the least possible amount of water. Broken stone, thoroughly cleaned from dust and dirt, drenched with water, but containing no loose water in the heap, will then be incorporated immediately with the mortar in such quantities as will give a surplus of mortar when rammed. This proportion when once determined to the satisfaction of the Board of Public Works, will be regulated by measure. Each batch of concrete will be thoroughly mixed, the mixing being continued on the board until each piece of stone is completely covered with mortar. It will then be spread and at once thoroughly compacted by ramming, until free mortar appears upon the surface. The whole operation of laying and mixing will be performed as expeditiously as possible with the use of a sufficient number of skilled men. No gravel will be used in the concrete, but only angular fragments of stone, having rough faces obtained by fracture, and measuring not more than two inches in their largest dimensions. The upper surface to be made exactly parallel to the surface of the pavement to be laid, and to be protected from the action of the sun and wind until set.

OTHER FACTS AND CONCLUSIONS.

Eminent engineers are authority for the following important conclusions:

1. Cold water is probably not injurious only as it retards setting.
2. All cements when mixed with sand to a proper consistence for mortar will fall to pieces if placed in water before setting has commenced. Portlands do so even without sand.
3. Pressure while setting, with the degree of the thoroughness of the mixing or gauging, the proportion of water used, and other considerations, *may easily affect the results one hundred per cent. or even much more.*
4. If too much water is present in mortar, the consolidation by ramming is proportionally imperfect.
5. Any American cement of good quality will with one and one-half to two measures of sand give a mortar strong enough for most engineering purposes.
6. American cements require less water than Portland.
7. Sand retards setting, so that cement which by itself would set in half an hour may not do so for some days if mixed with sand.
8. When one part sand is added to one part cement, the strength is lessened one-half. Two parts sand to one of cement averages about one-third the strength of pure cements. These for tensile and transverse strains. The crushing strength does not diminish so rapidly.
9. Brick or stone should be moist and entirely free from dust, or mortar will not adhere.
10. Slaked lime retards the setting of cement.
11. The temperature of air and water has far more influence in the setting of cements than has before been suspected.*
12. After using in air, cement or cement with sand, should be kept moist or watered until completely hard.
13. Walls of buildings are often built of cement concrete deposited between smooth faced planks as a mold, the planks being moved upward as the work goes on—concrete should be nearly dry and tamped hard.

*This new Portland mortar in air at 80° Fah. and kept in water 3 days at 40° had a tensile strength of 180 lbs. per square inch, while that kept in water at 70° had 280 lbs., or nearly twice as much.—Wm. W. McKay, C. E.

14. Post holes running down below frost and tamped full with concrete are safe and economical supports for warehouses and similar buildings.

15. Concrete may be used in large masses under water, and when properly put down, is found good for piers and shore protection.

16. One-quarter to one-half cement is a common rule of mixture for cement and lime for plaster-work in air.

17. Neither concrete nor cement can be emptied in water loose with good results, but must be conveyed to place in boxes or bags.

18. The white efflorescence most common to Portland cement is supposed to be injurious to the strength of brick and other materials.

19. Any disturbance of cement after setting commences is prejudicial to strength.

20. The best sand for concrete is that with angular coarse grains of uneven size. The more uneven the sizes, the less the voids, and the coarser the grains, the less quantity of cement required to cover the surface.

WEIGHTS OF CEMENT AND CONCRETE.

1. A BARREL of CEMENT weighs 265 lbs., net, averaging about $4\frac{1}{2}$ cubic feet, or the sixth part of a cubic yard, loose.

2. A CUBIC FOOT OF NEAT CEMENT, loose, weighs 55 to 60 lbs.

3. A CUBIC FOOT OF CONCRETE (cement, sand and stone), dry, weighs 130 to 160 lbs.*

4. A CUBIC FOOT OF CONCRETE, one part cement and two parts sand, by bulk, tamped solid, requires about 36 lbs. of cement.

5. A CUBIC FOOT OF CONCRETE, equal bulk of cement and sand, tamped solid, requires about 48 lbs. cement.

6. American Standard cements are similar in weight; but an extra light cement should be apportioned by weight, to secure equal results.

*Trautwine.

Superior Economy of American Cement.

Over five thousand tests by Mr. F. O. NORTON, of the American Society of Engineers, communicated to that Society in 1880, support the important conclusion by him that the mortar of good American cement, one part sand to one part cement, IS STRONGER AND LESS EXPENSIVE than a mortar of foreign Portland cement, consisting of two parts sand to one part cement; and that a mortar of good American, or natural cement, mixed with sand in the proportions named, is strong enough for all practical purposes generally required. In his noted paper on this subject Mr. Norton further says:

For fifty years past, and up to within a very short time, *all* the important masonry in this country has been laid with American cement. The great fortifications on the coast, the Croton Aqueduct, the Boston Aqueducts, both old and new, all the government dry docks, the lighthouses, the locks, culverts and aqueducts on the Erie and other canals; all the masonry of railroad bridges, viaducts and culverts, the sewers of our cities, the masonry of our gas works, many miles of wrought iron water pipe lined and laid in cement; the mills and mill dams in various localities; in fact nearly all the masonry built under water and out of water in the United States up to within a few years, have been constructed with American cement.

[The difference between artificial and natural cement, as shown by chemical analysis, furnishes no reliable ground for the inference that the former is superior in final strength. Artificial cement is characterized by a larger percentage of the carbonate of lime, and natural cement of good quality by a larger total percentage of the carbonates of lime and magnesia combined. Both these carbonates are active elements in cement, and are supposed to perform a similar service, except that the carbonate of magnesia, while less active, is more persistent, ensuring even higher ultimate results in the hardening process. These views are supported by the opinions of excellent authorities, as well as by all the indications in the extensive experiments of MR. NORTON.]

Sale and Shipment of Cement.

The following rules of the MILWAUKEE CEMENT COMPANY for the sale and shipment of cement are of general application in the western portion of the United States:

1. Cement is sold in BARRELS, GRAIN BAGS or PAPER SACKS, as the purchaser may prefer.

2. A BARREL OF CEMENT weighs 265 lbs., not including barrel.

3. A CAR-LOAD OF CEMENT usually means 100 barrels in barrels, or the cement contained in 180 grain bags, or in 400 paper bags.

4. The proper railroad weight of a car-load of cement in barrels, is 28,500 lbs; in grain bags, or paper sacks, 30,000 lbs.

5. Freight in car-loads is usually less than for smaller quantity.

6. Cement, stucco, land plaster and salt belong to the same class of freight, and usually all these articles are permitted to go in the same car; and if the aggregate weight is 24,000 lbs., or more, the whole will be charged at car-load rates.

7. Prices of cement per bbl. in car-loads will be given on board car at the mill, or on board car at place of delivery, as purchasers prefer—but for all shipments of cement in less quantity than 24,000 lbs., prices on board car at mill only are usually given.

8. The price of cement in grain bags, unless otherwise given, is 25 cents per barrel of 265 lbs. less than the price in barrels; and in paper sacks, 20 cents per barrel less than the price in barrels.

9. When cement is sold in grain bags, the bags are understood to be sold to the purchaser at 20 cents each, in addition to the price of the cement. But such bags will be paid for at same price if delivered at the mill in good condition, free of charge to the manufacturer, within sixty days after shipment. Paper bags are not to be returned. No empty grain bags will be received in payment of cement.

10. BAGS TO BE RETURNED should be safely tied together, in one or more bundles of convenient size, *and a card or tag securely attached to each bundle, giving the name of the sender. At the same time a bill of lading and invoice of same should be sent to the general office.*

11. All Milwaukee cement is tested before shipment, and warranted standard quality when shipped. Manufacturers do not hold themselves responsible for injury in transportation, poor sand, inexperienced tests, bad weather or ignorant manipulation. But cement claimed to be inferior to standard quality, will be impartially retested for the protection of dealers by standard methods, on receipt of sample, and the exact value verified.

12. Freights are payable by purchaser. In case of delivery price, supposed freight will be credited on invoice; if greater or less freight is actually paid, the original expense bill should be promptly forwarded to company by consignee for adjustment.

13. Accounts for cement in car-loads, unless contracted otherwise, are payable by draft at 60 days, dated first day of month after shipment. Acceptances should be written *across the face* of draft in substantially this form: "Accepted [date] payable at [name of bank, if any preferred]," signed by payer. Less than car-loads, cash during month of shipment.

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TESTIMONIALS.

OFFICE OF
CITY ENGINEER.

MILWAUKEE, March 15, 1890.

Milwaukee Cement Co., City:

GENTLEMEN:—Your letter of inquiry as to our experience with the cement manufactured by your company is received. The city has been using your cement in its public works more or less for the past twelve years, but more especially so during the last five years, during which time very extensive works, requiring an exceedingly large amount of first-class cement, were constructed.

During this period and up to the present time the most careful tests are being made of all cement before going into the work, and the result of these tests and the condition of the work shows your cement to have been very reliable and of a uniform quality and strength; they also show a very steady, considerable and constant increase of strength with age.

We have also had some astonishing results of the strength of concrete in which your cement was used. Your cement has given us the best of satisfaction in all our public works.

Yours very truly,

G. H. BENZENBERG,

City Engineer.

(Originator and promoter of the celebrated flushing tunnel.)

CHICAGO, MILWAUKEE & ST. PAUL RY.,
CHIEF ENGINEER'S OFFICE.

MILWAUKEE, March 24, 1890.

To the Milwaukee Cement Co., City:

GENTLEMEN:—As you are aware the Chicago, Milwaukee & St. Paul Railway Company have used your product ever since you commenced its manufacture on a commercial scale, an aggregate up to the present time of, approximately, 100,000 barrels, and never to my knowledge had cause to reject one barrel of it.

I should say that before commencing its use, and for years after, I made extended experimental tests not only of your product but of nearly all our American natural cements, with the result that yours excelled all others in all those qualities that are deemed of merit in a good natural cement.

Yours truly,

D. J. WHITTEMORE,

Chief Engineer.

(Ex. Pres't Am. So. Civil Engineers.)

MILWAUKEE CEMENT CO.—TESTIMONIALS.

C. H. BRINSMAID,
ASSISTANT CITY ENGINEER AND
CEMENT INSPECTOR.

CITY ENGINEER'S OFFICE,
MINNEAPOLIS, MINN., March 10, 1890.

Milwaukee Cement Co., Milwaukee:

GENTLEMEN:—Replying to yours of the 16th inst., would say that during the last four years we have used, in the construction of sewers alone, more than 50,000 barrels of Milwaukee Cement, which has proved uniformly reliable and satisfactory, as a constantly increased demand will testify.

The cement has shown better results each year in matter of strength and economy and, in my belief, is to-day surpassed by no other brand of natural cement in the market.

Respectfully yours,

C. H. BRINSMAID,
Ass't City Engineer and City Cement Inspector.

OMAHA, NEB., June 6, 1888.

Milwaukee Cement Co., Milwaukee:

GENTLEMEN:—Referring to your inquiry regarding your cement, would say: Milwaukee Cement has always given entire satisfaction.

Yours truly,

GEO. W. TILLSON,
City Engineer.

OFFICE
AMERICAN WATER WORKS CO.

OMAHA, NEB., June 2, 1888.

Milwaukee Cement Co.:

GENTLEMEN:—During the last two years in the construction for the American Water Works Co., at Omaha, I have used some four hundred car loads of your celebrated Milwaukee Cement, purchased of J. J. Johnson & Co., and it has given good satisfaction, and I deemed it an excellent hydraulic cement; am so pleased with it that I have this day made arrangements with J. J. Johnson & Co., for what cement the American Water Works may require at Denver, Col. and vicinity, to be used in their extensive construction at that point.

Very respectfully,

EDWARD RUGER,
Chief Engineer.

MILWAUKEE CEMENT CO.—TESTIMONIALS.

CHICAGO, MILWAUKEE & ST. PAUL RY.,
ENGINEER'S OFFICE.

MILWAUKEE, Sept. 13, 1889.

Milwaukee Cement Co., Milwaukee:

DEAR SIR:—"I can say this for the Milwaukee Cement, that it has been used exclusively on the road for many years for all work, excepting some few special cases of pointing, etc., where we have used Portland Cement, and our experience has made us entirely satisfied to continue its use."

Yours truly,

ONWARD BATES,

Asst. Eng., C., M. & St. P. Ry.

GEORGE A. FULLER,
CONTRACTOR AND BUILDER,
LA SALLE STREET.

CHICAGO, ILL., Sept. 4, 1889.

Milwaukee Cement Co., Milwaukee:

GENTLEMEN:—I have used large quantities of your cement during the past six years and it has always given entire satisfaction; and I can cheerfully recommend it to any one.

Yours truly,

GEO. A. FULLER.

DICKINSON BROS. & KING,
FOREIGN AND AMERICAN PORTLAND CEMENTS.

CHICAGO, March 12, 1890.

Milwaukee Cement Co., Milwaukee:

GENTLEMEN:—We take this opportunity of saying to you that we have handled thousands of barrels of your cement, distributing it in all classes of work in this city and vicinity and we have yet to receive the first complaint of its quality. We regard it as one of the best American Cements in the market and our customers all speak highly of its qualities, and those who try it once are always customers for this favorite brand thereafter. It sets slowly in some classes of work but always gets there just the same.

Yours truly,

DICKINSON BROS. & KING.

MILWAUKEE CEMENT CO.—TESTIMONIALS.

OFFICE
BARBER ASPHALT PAVING CO.

OMAHA, NEB., June 2, 1888.

Milwaukee Cement Co.:

GENTLEMEN:—The Barber Asphalt Paving Co. has used 65,000 bbls. of your cement in concrete under our paving in Omaha, every barrel of which has given perfect satisfaction to this company and the officials of this city.

Yours truly,

C. E. SQUIRES, *Gen'l Ag't.*

JAS. SMALL, *Sup't.*

MINNEAPOLIS, Oct. 14, 1889.

Milwaukee Cement Co., Milwaukee:

DEAR SIR:—Replying to your request as to Milwaukee Cement, we have used the cement in constructing the Library Bldg., Masonic Temple, Lumber Exchange, Corn Exchange, Kasota Blk, Donaldson Bl'k, Court House, and many other buildings of lesser note, and have to say that because of its great sand taking and generally slow setting qualities, convinces us that it is the best Natural Cement we have ever used. We know this from actual test, and cheerfully recommend it to those who may want a cement that is economical and one that grows in strength for an indefinite period.

Respectfully,

LONG & REES,

Architects.

TOPEKA, KAN., June 12, 1888.

Milwaukee Cement Co., Milwaukee:

GENTLEMEN:—Milwaukee Cement was used in about forty thousand yards of concrete here last season and is doing well, it has my preference over Louisville when mixed with sand mortar.

Yours truly,

GEO. T. NEALLY,

City Engineer.

MILWAUKEE CEMENT CO.—TESTIMONIALS.

CUTLER & GILBERT,
SALT AND BUILDING MATERIALS.

DULUTH, MINN., March 12, 1890.

Milwaukee Cement Co., Milwaukee:

GENTLEMEN:—Yours 11th inst. rec'd. We have sold your cement for several years and found it invariably reliable and of uniform quality.

The city has used large quantities in its sewers and bridge work always with good results. There is no question as to the value of your cement.

Respectfully yours,
CUTLER & GILBERT.

THE NORTHWESTERN LIME CO.
LIME, CEMENT, HAIR,
170 E. THIRD ST.

ST. PAUL, MINN., March 12, 1890.

Milwaukee Cement Co., Milwaukee:

GENTLEMEN:—We have been handling Milwaukee Cement in this section for the past eight years and during that time have sold many thousands of barrels for public works of all kinds. It has never failed to give entire satisfaction to every one who has used it, being very uniform in color and strength. It has a steadily increasing demand from all who have used it here and sales are constantly increasing.

Yours truly,
THE NORTHWESTERN LIME CO.,
Per H. D. MATTHEWS, *Prest.*

ANGUS & GINDELE,
MASONS AND GENERAL CONTRACTORS,
159 LA SALLE STREET.

CHICAGO, Sept 4, 1889.

Milwaukee Cement Co., Milwaukee:

GENTS:—For the last five years we have used your cement in various buildings in this city and have always found it satisfactory. We cheerfully recommend it to the trade.

Yours truly,
ANGUS & GINDELE.

MILWAUKEE CEMENT CO.—TESTIMONIALS.

E. P. BASSFORD,
ARCHITECT AND SUPERINTENDENT,
28 GILFILLAN BLOCK.

ST. PAUL, MINN., March 7, 1890.

Geo. S. Bartlett, Esq.:

DEAR SIR:—Thinking that a letter from me might be of service to you, I cordially recommend the Milwaukee Cement as an excellent article. I have used large quantities of it and always found its uniting, tying and setting qualities first-class.

EDWARD P. BASSFORD.

And would cordially recommend it to any admiring such qualities. A new move, especially to municipal corporations who issue certificates of marriage. And think if that cement could be worked in, there would be no separations or divorce suits to hamper courts of justice.

Respectfully,

E. P. BASSFORD.

KANSAS CITY, MO., April 1, 1889.

Milwaukee Cement Co., 154 W. Water St., Milwaukee.

GENTS:—Having used your cement on many important works, both stone and brick, and always with the most satisfactory results, I do not hesitate in saying that I know of no better cement for the many purposes it can be used, than yours.

Yours respectfully,

L. L. LEVERING,

Architect.

Hundreds of other Testimonials on file from eminent engineers, architects, and others, who have used this justly celebrated hydraulic cement.

MILWAUKEE CEMENT.

No better demonstration could be made of the superiority of the Milwaukee cement, and uniformity of its manufacture, than the following references to those who have actually used and tested it:

Railroad Work.—From S. S. MERRILL, late General Manager C., M. & St. Paul Ry.: The Chicago, Milwaukee & St. Paul Ry. Co. has used Milwaukee Cement in *all its important works* for the last five years. From D. J. WHITTEMORE, late President American Society Engineers, and C. E. C., M. & St. Paul Ry.: The C., M. & St. P. Ry. Co. has used over 200,000 barrels Milwaukee Cement. All its railway bridges across the Mississippi river are constructed with it. I make frequent exact tests of the quality of all typical brands of American Cement, and certify that there is no hydraulic cement in the market superior to the Milwaukee. OTHER REFERENCES: C. & N. W.—C. B. & Q.—A. T. & S. F.—Penn. Co.—B. & M.—Northern Pacific—Canadian Pacific—W. C. Ry.—M., L. S. & W.—C. B. & N. Ry.—S. C. & P. Ry.—F. E. & M. V. Ry.—U. P. Ry. and others.

Pipe and Artificial Stone.—From H. BERTHELET & Co., manufacturers Cement Pipe: We are manufacturing large quantities of concrete sewer pipe from Milwaukee Cement. A large number of tests made by us at our factory in this city, show that pipe made with Milwaukee Cement is much stronger than the imported Scotch vitrified pipe, as shown by foreign tests, or than concrete pipe manufactured from any other natural cement hitherto in market. We use it exclusively. FROM RACINE CEMENT AND PIPE CO.: *All concrete composed of two parts sand and one part Milwaukee Hydraulic Cement, when mature, will be as strong and durable as a rock.* The carbonizing process will ensure this result in six days. We find the best brands for sewer, well and culvert pipe, cement fences, side-walks, blocks for houses, foundations, etc., the Milwaukee natural cement, except for surfaces exposed to immediate wear, for which we sometimes use a small proportion of artificial cement.

Bridge Work.—From ALEXANDER MITCHELL, President C., M. & St. Paul Ry. Co.: Milwaukee Cement was used by the C., M. & St. Paul Ry. Co. in building the bridge across the Mississippi river at La Crosse, and gave *entire satisfaction*. From PRICE BROTHERS, Bridge Contractors: We must say your cement is the best cement we have ever used in this country—the best Rosendale not being better. We have used a large quantity in bridge work. OTHER REFERENCES. C., M. & St. Paul Ry. bridges at Sabula, La Crosse, St. Paul, Minneapolis, all their bridges and retaining walls at Milwaukee; C. B. & Q. bridge at Plattsmouth and other bridges on same line; C. & N. W. Ry. bridges at Milwaukee and Chicago and elsewhere on that line; bridges on the lines of M. L. S. & W. Ry. and W. C. Ry.; C. B. & N. Ry. bridges at Galena, Prairie du Chien and elsewhere on the line, and other bridge work at Milwaukee, across Menomonee and Milwaukee rivers, and numerous others in all parts of the West.

Sewer Work.—From MOSES LANE, C. E., late Prest. Board of Public Works, Milwaukee: Milwaukee Cement is in our opinion, as good as any brand of American cement in the market. From S. A. ROBERTSON, Contractor and Builder, Des Moines, Iowa: I have used in my contracting, and what I have sold, several thousand barrels of Milwaukee Cement. I have made use of it for concrete, for foundations, brick and stone masonry, cellar floors, cisterns and building sewers in this city. For all these uses and for any other that American cement is used, the Milwaukee is as good as any made in *this* country. OTHER REFERENCES: Sewers in Milwaukee, Chicago, St. Paul, Minneapolis, Omaha and all other principal cities of the Northwest.

Pavement.—From Maj.-General Q. A. GILLMORE, U. S. Engineers: The cement (Milwaukee) has been used in the foundation of Pennsylvania Avenue pavement, Washington City, with entire satisfaction. OTHER REFERENCES: Pavements at Omaha, Kansas City, St Paul, etc.

Public and Private Buildings.—From ALEXANDER MITCHELL, Pres. of the Chicago, Milwaukee & St. Paul Railway: I have used Milwaukee Cement in the construction of my new Bank Building, and in the new Chamber of Commerce Building, and it has given great satisfaction. From R. S. FINKBINE, Superintendent Iowa State Capitol: We have used Milwaukee Cement for three years on the new Capitol Building. We have used it for concrete, for brick work and for laying slate on porous tile. We first used Portland for laying roof-slate, but the Milwaukee, on trial, gave such good results that we substituted it for the Portland. We have just completed a stack foundation of Milwaukee Cement concrete, made in and setting under water. I regard the Milwaukee as equal to any hydraulic cement I have ever used. From A. E. MARTIN, Warden and Superintendent Iowa Additional Penitentiary, Anamosa, Iowa: I used Milwaukee Cement in the construction of the Additional Penitentiary at Anamosa. Every barrel has been of excellent quality. I consider it equal to, if not superior to any American cement in this market. OTHER REFERENCES: Union Depot, Standard Opera House, Washington Park Club House, C. B. & Q. Freight House, P. C. & St. L. R. R. Freight Houses, New Board of Trade Building, South Branch Pumping Works, Cook County Hospital, Royal Insurance Building, Home Insurance Building, Phoenix Distillery, Chicago Avenue Viaduct, Harrison Street Viaduct, Polk Street Viaduct, Lake Street Bridge, Cook County Insane Asylum, Swift Packing House, Union Stock Yards, C. & N. W. Ry. Freight Houses, Chicago Sugar Refinery, American Express Building, Kimball Organ Factory, and 1,000 ware-houses, breweries, factories, private residences and other buildings in the city of Chicago; St. Paul & N. P. Ry. Shops, St. Paul & N. P. Ry. Bridge, N. P. Ry. Shops, N. P. Ry. Freight House, City Sewers, Minnesota Loan & Trust Company Building, C., M. & St. P. Ry. Viaduct, South Minneapolis Bridge, Third Street Bridge, Union Depot Building, Union Depot Retaining Wall, U. S. Government Buildings, etc., at Minneapolis; U. S. Court House and Post Office, St. Mary's Cathedral, National Hotel, Masonic Temple at Peoria, Ill.; Court House, City Sewers, Ryan Hotel, Robert Street Bridge and other public and private buildings at St. Paul, Minnesota; Mandan Roller Mills, Mandan, D. T.; State Capitol, Topeka; State Capitol, Lincoln; Capitol, D. T.; Government Buildings at Topeka, Memphis, St. Louis, Milwaukee, Traverse City, Madison, Oshkosh, Minneapolis, Minn.; St. Paul, Minn.; Omaha, Nebraska, Council Bluffs, Ia.; Des Moines, Ia.; Marshalltown, Ia.; Clarinda, Ia.; Carbondale, Ill.; Peoria, Ill.; Adrian, Mich.; St. Joe, Mo.; Kansas City, Mo.; Leavenworth, Kas.; Atchison, Kas., etc.

Government Works.—From D. C. HOUSTON, Major of Engineers, Bvt. Col. U. S. A.: We have used large quantities of Milwaukee Cement. I have reason to believe that for general use the Milwaukee Cement is of excellent quality, and when we have used any other cement in Government work, it has been purchased as a matter of convenience, and not because it was considered superior to the Milwaukee Cement in quality. From D. W. FLAGLER, Lt. Col. of Ordnance, Rock Island, Ill.: I have used the Milwaukee Cement Company's cement on various kinds of work during the past seven years. The company has performed their business promptly and to my entire satisfaction. My tests and actual use of this cement have proved that it ranks among the best of American cements.

Gas Works.—From W. A. AGARD, Manufacturer, Capital City Gas Light Works, Des Moines, Iowa: We have used Milwaukee Cement since the fall of 1876, for gas holders, tank foundations and other work, and consider it the best American cement we have used. Gas Works at Milwaukee, Ashland, Minneapolis, Chicago, Appleton, and Hyde Park, Ill.

Water Works.—From EDWARD SLATTERY, Contractor and Mason, Niles, Michigan: I have used your hydraulic cement in the Niles Water Works, and find it, in my estimation, superior to any American cement manufactured, artificial or natural, with the merits of all of which I am familiar. Your cement in its action, and value in work, is nearer to the noted imported cements than any that I have ever used, and I cheerfully give it my hearty and unqualified endorsement as a reliable hydraulic cement for any and all purposes. OTHER REFERENCES: Water Works at Appleton, St. Paul, Ottumwa, Adrian, Milwaukee, Hyde Park, Omaha, Denver, Denver, etc.

Floor Tiling.—I have used Milwaukee Cement in laying English floor tiling and hearths continuously for the past four years, and I have been in the business in the employ of Henry Dibble, Chicago, ten years. I regard the Milwaukee Cement as the best cement that can be obtained for the purpose. It becomes harder and is more reliable than Portland. I refer to Opera House, Kalamazoo; National Bank, Omaha; six or seven large saloon floors in Chicago; Plankinton House, Milwaukee; Second Ward Bank, Milwaukee; Opera House, Racine; National Soldiers' Home, Milwaukee; Jefferson Court House, and a large number of other public and private buildings in various states.—WILLIAM SANDY.

